INVESTIGATION OF NUISANCE ALGAE AND WATER QUALITY OF STOCO LAKE 1984

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SUMMARY

During 1984 the Ministry of the Environment conducted a water quality survey of Stoco Lake. The survey was undertaken in response to numerous reports of a severe and prolonged accumulation of nuisance algae along the northeastern shore of the lake near Greenwood Park. The survey examined the chemical and biological water quality of Stoco Lake with specific regard to the level of nutrient enrichment and sources of nutrient inputs to the lake.

A phosphorus nutrient budget was developed for Stoco Lake to assess the significance of various sources of phosphorus to the lake. Phosphorus affects the abundance of algae. If more of it is supplied more algae will grow. With less phosphorus in the water there is less algae. The water quality of Stoco Lake is dominated by the water chemistry of its major tributary, the Moira River. The Moira River provides 76% of the inflow and 56% of the total phosphorus supply to the lake. The phosphorus supplied to Stoco Lake by the Moira River is augmented during the summer months by release of phosphorus from bottom sediments. Phosphorus is released to overlying waters during periods of oxygen depletion in the bottom of the lake. This internal source of phosphorus is important as it provides a continual supply during the height of the growing season for aquatic plants, including algae, at a time when the tributary inflows are much reduced. The high chlorophyll concentrations of Stoco Lake are a reflection of high algal levels and can be attributed to the various sources of phosphorus identified in the nutrient budget in the report. Even in the absence of the artificial sources of phosphorus from septic tank leachate and the Village of Tweed sewage lagoon treated effluent, Stoco Lake would remain a very productive body of water.

Data from previous water quality surveys indicate that algal levels during 1984 were within the normal range experienced for Stoco Lake. While the high chlorophyll concentrations in the previous years have undoubtedly detracted from the recreational attractiveness of the

lake, there had been no previous complaints to the Ministry of the Environment of nuisance algal conditions. Blue green algae float on the surface of the lake. A light breeze that just skims the surface of the water can concentrate a large amount of algae on a downwind shore. The nuisance conditions near Greenwood Park were apparently the result of wind induced concentration along the shoreline of a large algal mass which developed on the open waters of the lake.

INTRODUCTION

Previous water quality surveys (1968, 1972-1975) have shown that Stoco Lake is extremely fertile with abundant growths of aquatic weeds and algae. Excessive blooms of blue-green algae (see Fact Sheet: Algae - What are Algae - Appendix 1) occur frequently during the summer months. A prolonged bloom of unusual severity which began in July, 1984 was reported by numerous residents of the Greenwood Beach area of Stoco Lake.

The purpose of our study was to investigate the complaints of nuisance algal accumulations and to re-examine the trophic (nutrient related) water quality of Stoco Lake as it pertains to the problem of recurring algal blooms. Water quality data obtained from this investigation, historical Provincial Water Quality Network (PWQN) records and the previous lake surveys were used to develop a nutrient budget for the lake in order to assess the significance of the various sources of phosphorus supplies. The potential effect of phosphorus supplies including the domestic sewage effluent from the treatment lagoons serving the Village of Tweed were evaluated in the context of existing water quality conditions.

The water quality surveys of Stoco Lake in 1968 and 1972 identified untreated municipal sewage discharges from the Village of Tweed as a source of widespread bacteriological contamination of the lake as a result of dispersion of sewage input by the Moira river inflow. During the late 1960's and early 1970's the local Health Unit posted the public bathing beach at Tweed Memorial Community Park as unsuitable for swimming because of unacceptable levels of fecal coliform bacteria in the water.

A new sewage system consisting of a collection works, pumping stations and a two-cell, seasonal retention, waste stabilization lagoon was placed into operation in 1975 (see Fact Sheet: About Sewage Treatment - Appendix 2). Some bacteriological sampling was undertaken during

the present investigation to ascertain the degree of improvement in bacteriological water quality as a result of the upgrading of sewage disposal practices at Tweed.

DESCRIPTION OF STUDY AREA

Stoco Lake is adjacent to the Village of Tweed (population 1,584) 35 kilometres north of the City of Belleville in Hungerford Township of Hastings County (Figure 1). It has a surface area of 500 hectares (ha.), a maximum depth of 11 metres with a mean depth of 4 metres, and 16.6 kilometres of shoreline. It supports an excellent warm water fishery and is well developed with over 200 private residences, 2 trailer parks and 9 resort cottages. The lake is thus an important recreational and economic asset to the Village of Tweed and surrounding area.

The lake and its immediate drainage basin are located in the Precambrian shield and are part of the Moira River watershed. The soil and terrain of the area immediately surrounding the lake have been described in detail by the Ministry of the Environment (1972, 1974) and the Department of Planning and Development in the Moira River Conservation Report (1955). The land use within most of the immediate Stoco Lake area is primarily agricultural (OMAF, 1983) while the head waters of the watershed are largely forested with a mixed deciduous and coniferous cover.

A short distance upstream of Stoco Lake, three rivers; the Moira River proper, the Black River and the Skootamatta River join to form the major inflow to the lake. Combined, these three rivers drain an area of 1,770 square kilometres of the watershed. There are two other inlets; the Clare River draining an area of 303 square kilometres which forms the northeastern portion of the watershed and Sulphide Creek which flows into the north end of the lake draining an area of 157 square kilometres. These minor tributaries originate in extensive areas of continuous marshes interconnected by small lakes, ponds and streams.

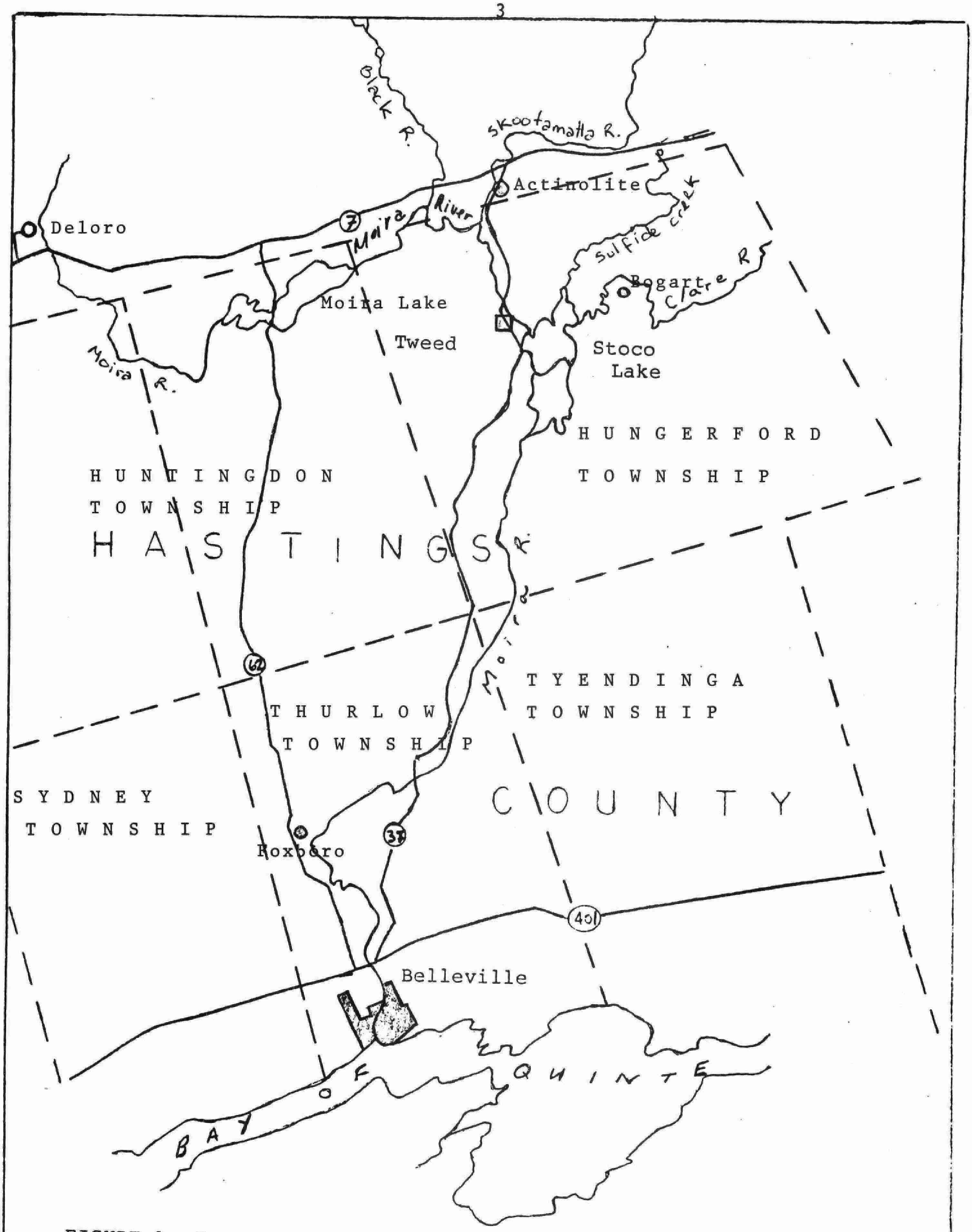


FIGURE 1: Geographic location of Stoco Lake

There are only two outlets; namely, the East Channel and West Channel at the south end of the lake. They converge about two miles downstream to reform the Moira River. Dams on the East Channel and the West Channel are owned and operated by the Moira River Conservation Authority primarily for the purpose of controlling water levels in Stoco Lake to enhance its recreational use.

Four years of continuous discharge data (1972-1975) have been collected by Environment Canada from a stream flow recording station (O2HL101) on the Moira River at Tweed and six years (1970-1975) from a station (O2HL102) on the Clare River at Bogart. Longer term flow data are available for the Moira River at Deloro (Station 02HL005), the Moira River at Foxboro (Station 02HL001) the Skootamatta River at Actinolite (Station 02HL004), and the Black River at Actinolite (Station 02HL003). Stream flows in cubic metres per second for the periods of record and for 1984 at these sites are summarized in Table 1.

Table 1: Stream flow (m^3/sec) Within Moira River Basin

Watercourse	Gauge	Period of Record	Mean Monthly Flow min.	Mean Monthly Flow max.	Mean Flow for Survey Period 1984
Moira River	Deloro	1965 - 1984	0.01	21.3	0.16
Black River	Actinolite	1956 - 1984	0.07	35.2	1.14
Skootamatta River	Actinolite	1956 - 1984	0.155	58.1	0.65
Moira River	Tweed	1970 - 1975	0.721	127.0	
Clare River	Bogart	1970 - 1975	0.029	18.1	
Moira River	Foxboro	1916 - 1984	0.795	216.0	5.52

Data were obtained from published records for the years 1916 - 1983 and from provisional records for the year 1984 of the Water Resources Branch of Environment Canada.

About 60% of the annual discharge to Stoco Lake occurs during the spring runoff months of March, April and May while in most years less than 5% of the annual volume is provided by low flows during July, August and September.

The available stream flow records were utilized to prorate and project flows into Stoco Lake from the Moira River, the Clare River and Sulphide Creek. These calculations in turn allow estimates of the total water budget and flushing rate of Stoco Lake.

The major morphometric and hydrologic features of Stoco Lake are summarized in Table 2.

Table 2: Major Morphometric and Hydrologic Characteristics of Stoco Lake

Surface area[1] (A_o)	500 ha.
Maximum depth[1] (z_{max})	9.8 m
Mean depth[1] (z)	4.0 m
Volume[1] (V)	19.93×10^6 m^3
Shoreline length[1] (L)	16 km
Drainage area[2] (A_d)	2230 km^2
Annual inflow/outflow (Q)	993×10^6 m^3
Areal water load[3] (q_s)	198 m
Flushing rate[4] (p)	50 x annually
Response time[5] (t)	0.06 yr.

1. Source: Ontario Department of Lands and Forests Lake Survey Summary 1969.

2. Planimetric measurement from Canadian topographic sheets at 1:50,000 scale.

3. Areal water load is the annual inflow volume expressed as a height above the surface area of the lake (Q/A_o).

4. Flushing rate is the number of times that the volume of water contained by the lake is displaced by inflow in a given period of time - a year (Q/V).

5. Response time (Dillon, 1975) is the time required for the phosphorus concentration to reach an equilibrium condition for the phosphorus supply to a lake.

SURVEY METHODS

Sampling Period and Station Locations

From July 24 to October 29, 1984, nine sampling visits to Stoco Lake were made.

A single sampling station was located in the center of both the north basin (1) and the south basin (2) of Stoco Lake at approximately the sites of their maximum depths (Figure 2).

To assess the chemical nature of the inflowing and outflowing water and to examine for possible sources of nutrient enrichment, a sampling station was established on each of the Stoco Lake inflows - Moira River (M1), Clare River (C1) and Sulphide Creek (S1) - at a point just upstream of their entry; and at the Stoco Lake outlets - West Channel (M2), and East Channel (M3).

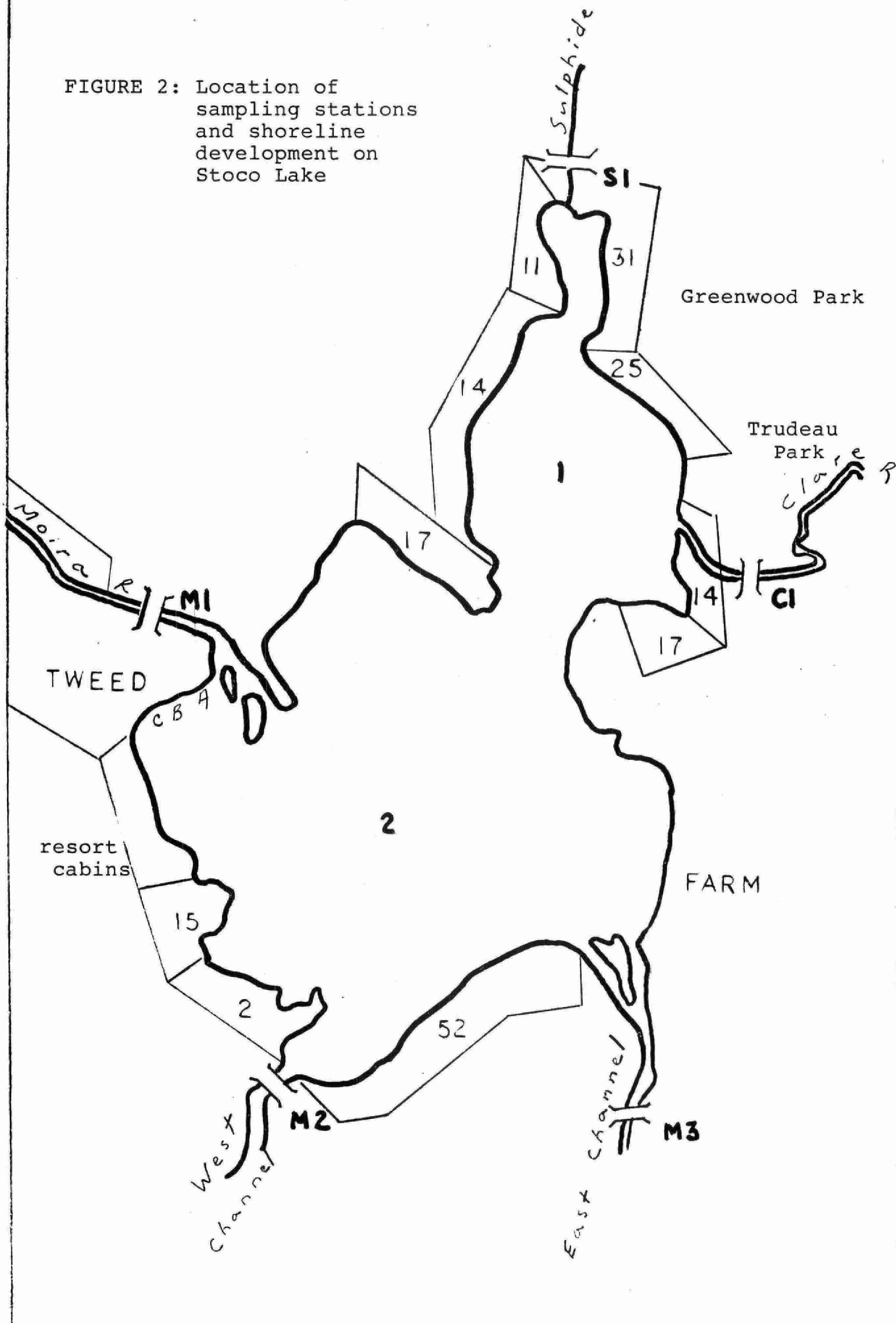
Bacteriological sampling was carried out at the two mid-lake stations (1 and 2) and at three sites (A, B, C) from a third lake location in close proximity to the municipal bathing beach at Tweed.

All of the lake, tributary and bacteriological sampling locations are shown on the map of Stoco Lake in Figure 2.

Water Clarity Measurements

Water clarity is one of the most important characteristics of a lake from a recreational and aesthetic point of view. In most lakes, water clarity is determined primarily by the abundance of phytoplankton or algae in the water. A lake becomes progressively more turbid and water clarity declines as phytoplankton become increasingly abundant.

FIGURE 2: Location of sampling stations and shoreline development on Stoco Lake



Water clarity was measured on each visit to the lake with a Secchi disc (a steel plate 20 centimetres in diameter, painted in opposing black and white quadrants). The depth at which the disc just disappears from view when lowered into the lake is a measure of water clarity.

Chlorophyll and Phytoplankton Collections

The abundance of phytoplankton in a lake can be determined directly by microscopic enumeration of the algae present, or indirectly by chemically measuring the amount of chlorophyll (a green pigment contained by the algae) in a sample of water. Because of the ease and rapidity with which chlorophyll determinations can be made they are the more commonly employed method.

Collections for phytoplankton and chlorophyll analyses were taken from the lake as composites through the euphotic zone (the depth of effective light penetration for photosynthesis). The euphotic zone is estimated as being twice the Secchi disc visibility depth. Chlorophyll and phytoplankton samples were preserved immediately after collection. Chlorophyll samples were preserved with five drops of a 1/2% suspension of magnesium carbonate ($MgCo_3$). Phytoplankton samples were preserved with Lugols iodine solution.

Chlorophyll samples for each sampling date were analysed individually while, phytoplankton samples collected at each of eight visits to Station 2 and each of seven visits to Station 1 were pooled to form a single composite sample for each location prior to identification and enumeration. The analysis of a composite sample characterizes the "average" composition of the phytoplankton population and therefore draws attention to the relative densities of desireable and undesireable algae.

Water Chemistry Sampling

Near-surface, lake samples were collected for chemical analyses at 1.0 m of depth or as euphotic zone composites. Bottom-water samples were collected at 1.0 m above bottom at the two lake stations. Water samples were collected as surface grabs at the five stream stations.

Determination of chemical water quality involved the evaluation of the concentrations and distribution of the following parameters:

Hardness	Total Phosphorus
Alkalinity	Soluble Phosphorus
Conductivity	Ammonia
pH	Total Kjeldahl Nitrogen
Calcium	Nitrite
Magnesium	Nitrate
Chloride	Iron
Colour	

The analyses were carried out by the Kingston Regional Laboratory according to standard methods of the Ministry of the Environment.

Dissolved Oxygen And Temperature Profiles

The mid to late summer vertical distribution of dissolved oxygen and water temperature can be used to explain many of the conditions encountered and to estimate the potential for the occurrence of specific water quality problems in lakes. Dissolved oxygen and temperature profiles from surface to bottom were measured at the lake using a Y.S.I. model 54 meter. The meter was calibrated daily and checked frequently with a wet reagent Winkler test kit using freshly prepared sodium thiosulphate (0.0125 N) as a titrant.

Bacteriological Sampling

Bacteriological water quality indicators are groups of bacteria whose densities in water can be related to the presence of sewage or fecal matter, and therefore the risk of contracting disease from pathogens that might also be present. Fecal coliforms are one of those indicators. Water quality is considered impaired when the geometric mean densities for a series of water samples exceeds 100 per 100 ml.

Subsurface samples were obtained by hand with pre-sterilized bottles. The samples were stored on ice in the field and returned to the laboratory. They were refrigerated pending analysis and were usually analyzed within 24 hours of collection.

RESULTS

All physical and chemical data pertaining to the survey are contained in Appendices 3 to 4. Historical data from the Provincial Water Quality Network (PWQN) are included to allow a more meaningful assessment and interpretation of the results of the present study.

Algae Complaint Investigation

Complaints by residents of the Greenwood Park and Trudeau Park areas of the north shore of Stoco Lake concerning excessive accumulations of algae and offensive odours were investigated on July 24 and August 7, 1984.

On the July 24th inspection, a heavy suspension of fine green algal particles was observed in fairly clear water throughout the lake. Accumulations of this algal material had formed and were observed clinging to rooted aquatic plants and other submerged objects in shallow water areas.

Residents at Greenwood Park reported that a "pea soup" scum blanketed the entire bay to a distance several hundred feet off shore on Saturday, July 21 and Sunday, July 22. The problem had largely dissipated by the time of our inspection, but a band of decaying algae was observed along the water line and in piles which had been raked onto the beach. Samples of algae were collected from on shore and from the lake in the vicinity of Greenwood Park and were subsequently identified as *Lyngbya* and *Oedogonium*.

Samples of water collected from the lake near the mouth of the Clare River at the time of the August 7th investigation contained only Lyngbya.

Nuisance accumulations of algae were not observed elsewhere on Stoco Lake. A resident of Greenwood Park commented that use of the municipal beach at Tweed had continued uninterrupted over the weekend when conditions at Greenwood park had precluded any shoreline use. Observations made during our lake visits together with the absence of complaints from other areas of Stoco Lake indicate severely adverse water quality conditions were localized to the Greenwood Park area of the north shore during 1984.

Water Clarity

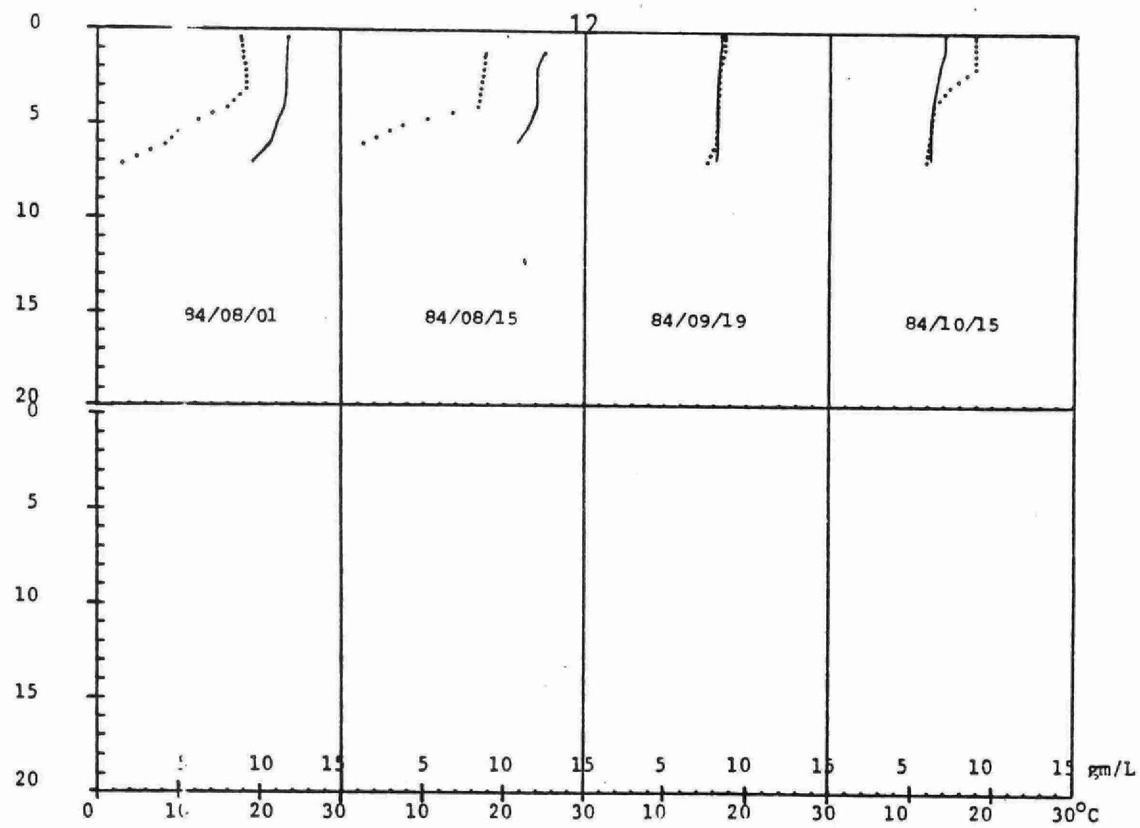
Secchi disc measurements (Appendix 3) indicated little difference in water clarity of the north and south basins of Stoco Lake. The mean Secchi disc visibility depth for the entire lake was 1.2 metres. Individual values ranged from 0.8 to 1.8 metres except for the last visit on October 15, when readings of 3.0 metres were recorded. Water clarity showed a slight deterioration from an average Secchi disc visibility of 1.3 to 2.4 metres measured between 1972 and 1975.

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature data are presented graphically in Figure 3.

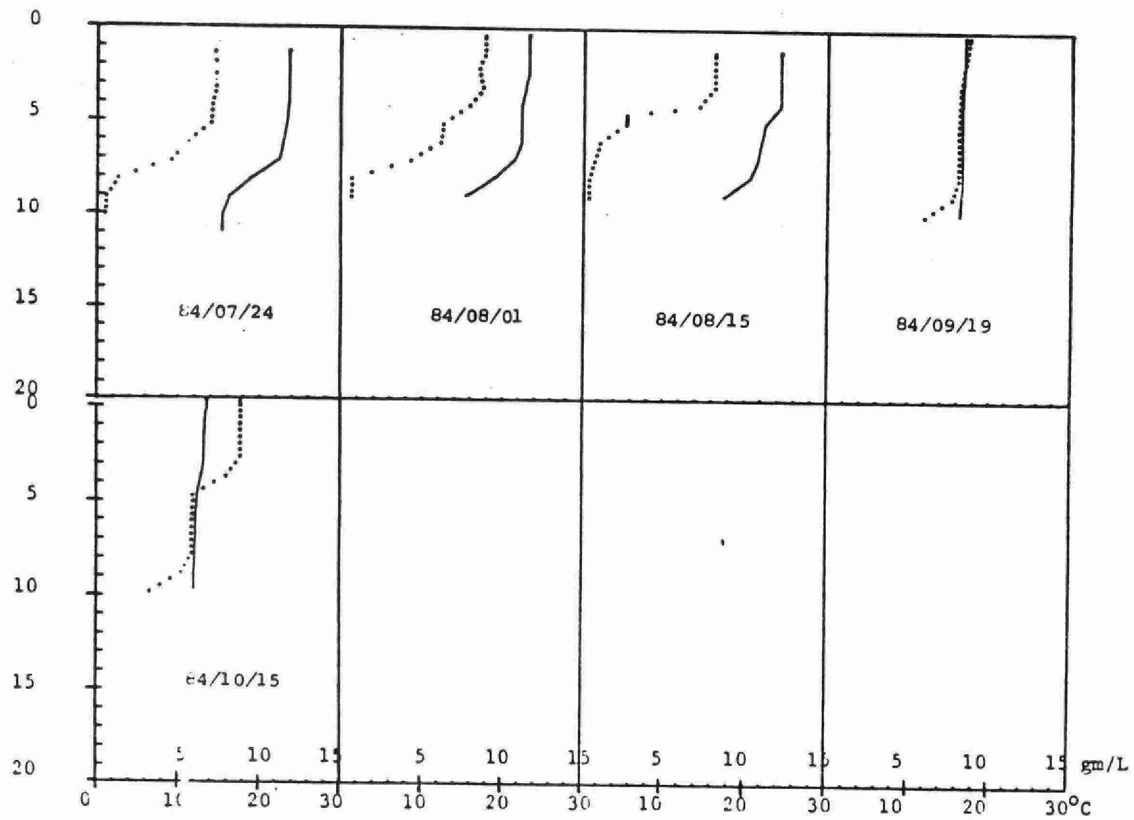
A weak thermocline (decrease in temperature greater than 1° C with each metre of depth) was apparent below seven metres in the thermal profile for the south basin (station 2) on July 24 and August 8; otherwise temperature gradients were generally gradual and thermal profiles presented no evidence of any well defined or persistent thermal stratification.

STOCO LAKE



Dissolved Oxygen (....) and temperature profiles (___) at Station 1

STOCO LAKE



Dissolved Oxygen (....) and temperature profiles (___) at Station 2

FIGURE 3:

Dissolved Oxygen and Temperature profiles with Depth for Stoco Lake

Dissolved oxygen concentrations in the surface waters ranged from 7.3 mg/l to 9.3 mg/l representing saturation or near saturation values while concentrations near zero were recorded at one metre above the lake bottom from July 24 to August 15. By September 19 any vestige of thermal stratification was absent from Stoco Lake and both dissolved oxygen concentrations and temperatures were essentially uniform from surface to bottom. On October 15, although the lake was uniform in temperature from surface to bottom, dissolved oxygen declined with depth from 8.8 mg/l at the surface to 5.7 mg/l at 7.0 metres at Station 1 and from 8.9 mg/l at the surface to 3.3 mg/l at 10 metres at Station 2.

Water Chemistry

The conductivity of the north basin was consistently slightly higher than the south basin reflecting a greater concentration of dissolved substances from the inflows of the Clare River and Sulphide Creek compared with the Moira River inflow. Overall, the surface water of the entire lake had a mean conductivity of 195 umhos/cm, a mean hardness of 100 mg/l, a mean alkalinity of 90 mg/l, and a relatively stable and slightly alkaline pH in the range of 7.7 to 8.7. These results indicate that Stoco Lake has moderately hard water without any unusual mineral characteristics.

Iron

Concentrations of 0.10 to 0.15 mg/l of iron were detected in the surface water. A singularly high value of 1.0 mg/l occurred at the bottom water of station 2 on August 15.

Colour

Surface water dissolved colour was barely perceptible ranging from 16 to 48 hazen units. Bottom water was typically more coloured than the surface water with levels approaching 200 hazen units for station 2 on August 15 and August 20. These increases of bottom water colour are likely imparted by the release of iron from lake sediment under anoxic (no oxygen) conditions.

Nutrient Levels

Total phosphorus concentrations in the surface waters were high, ranging from 26 to 58 ug/l with an overall average of 38 ug/l for the two basins combined. Nuisance levels of algae can be expected to occur in lakes having phosphorus concentrations in excess of 20 ug/l. Total nitrogen concentrations averaged 777 ug/l. The biologically available inorganic fraction (sum of NH_3 + NO_2 + NO_3) was low with levels not exceeding 40 ug/l. The inorganic fraction is a form of nitrogen that is directly assimalated by algae or readily oxidizable to a form that is directly assimalated.

Total nitrogen and total phosphorus levels in the bottom waters were similar to the surface water levels except on August 20 when extremely elevated concentrations of both nutrients were found under anoxic conditions at station 2. Total phosphorus concentration was 106 ug/l and the total nitrogen concentration was 1372 ug/l. Bottom water ammonia nitrogen levels exceed surface values throughout the survey with a range of 60 ug/l to a very high value of 730 ug/l at station 2 on August 20.

The Secchi disc readings and mineral and nutrient concentrations, including the pattern of intermittently high phosphorus and nitrogen concentrations in the bottom waters, are comparable with the results of the previous water quality surveys of Stoco Lake 1972 - 1975 (Table 3).

Table 3: Water quality characteristics of Stoco Lake 1972 - 1975 and 1984 as represented by the means and ranges of total alkalinity (alk), conductivity (cond.), total phosphorus (TP) and total nitrogen (TN).

Year	Alk. (mg/l)	Cond. (umho/cm)	TP (ug/l)	TN (ug/l)
1984				
Surface	88 (79-94)	192 (180-200)	38 (26-58)	777 (682-892)
Bottom	87 (80-94)	194 (185-204)	46 (26-106)	801 (578-1372)
1975				
Surface	78 (62-124)	183 (155-266)	29 (14-56)	616 (412-1022)
Bottom	74 (60-122)	174 (135-275)	51 (18-78)	599 (192-1050)
1974				
Surface	73 (64-81)	180 (169-192)	34 (19-86)	616 (290-631)
Bottom	72 (63-88)	171 (160-185)	141 (22-1200)	813 (412-3530)
1973				
Surface	76 (73-80)	209 (177-269)	39 (11-65)	813 (465-1614)
Bottom	76 (70-86)	209 (154-269)	56 (19-120)	646 (420-1012)
1972				
Surface	78 (71-88)	182 (165-200)	38 (24-48)	741 (590-890)
Bottom				

Chlorophyll and Pytoplankton Standing Crops

Mean monthly concentrations of chlorophyll measured during 1984 and between 1972 and 1975 are summarized in Table 4. The annual average chlorophyll concentration during 1984 was 16.8 ug/l with an individual sample range of 5.4 ug/l to 24.4 ug/l.

The earlier survey data (1972-1975) for chlorophyll levels indicate that Stoco Lake exhibits a tendancy to experience pronounced algal blooms during the latter part of July and August. Extremely high chlorophyll concentrations were observed during these months in 1973 and 1975 with peak values of 45 ug/l and 46 ug/l, respectively. These concentrations are well in excess of the maximum concentration determined in 1984, but there is no record of complaint notifications received by the Ministry of the Environment for either of those two years.

Table 4: Range and mean of monthly chlorophyll a concentrations (ug/l) in Stoco Lake 1972-1975 and 1984.

	1984	1975	1974	1973	1972
May		2.4 (1 Sample)	2.4 (2.2-2.7)	4.5 (2.5-6.5)	
June		4.7 (1.4-6.5)	4.5 (2.9-5.9)	5.1 (3.0-7.6)	8.0 (6.8-9.3)
Jul.	5.4 (1 Sample)	9.9 (1.5-20.0)	1.8 (1.1-3.1)	18.8 (3.7-45.0)	
Aug.	18.8 (15.1-24.4)	30.8 (19.0-46.0)	5.6 (4.5-7.3)	25.3 (8.2-35.0)	6.4 (3.0-9.0)
Sept.	15.9 (6.3-21.4)		6.5 (1 Sample)	15.5 (14.0-17.0)	3.4 (1.7-7.4)
Oct.		6.5 (1 Sample)			

The extent to which high chlorophyll concentrations cause nuisance conditions depends on a number of factors. While all types of algae contribute to the chlorophyll concentration, abundant growths of certain algal species, particularly among the blue- green algae, are more objectionable from a water quality standpoint than other less noxious algae such as diatoms or green algae. The pseudovacuoles (celluar cavities) of some blue-green algae cause them to float high in the water and concentrate near the surface forming conspicuous algal

blooms. Usually, wind induced mixing and wave action redisperses the algae uniformly throughout the water column and the lake. Their abundance is apparent primarily as a reduction in water clarity. However, a light breeze that just skims the surface of the lake can concentrate algae floating on the surface into conspicuous accumulations along a downwind shore.

Results for the regular phytoplankton sampling conducted at the two mid lake stations indicate that blue-green algae comprised 87% of the total cell volume for the study (Appendix 6). Anabaena and Aphanizomenon ranked first and second in abundance, respectively. Both of these genera contain nuisance species that are notorious bloom formers.

Total celluar biovolume averaged 2.053 x $10^6 um^3$/ml for the south basin and 3.512 x $10^6 um^3$/ml for the north basin. These levels are extremely high. The predominance of bloom-forming, blue-green algae and the concentrating effect of a prevailing southwesterly wind pattern coincided during 1984 to produce an acute localized nuisance along the shoreline of the Greenwood Park development.

Bacteriological Water Quality

The results of the bacteriological sampling conducted on Stoco Lake are summarized in Table 5. Results for the beach area are presented as geometric mean values for the three samples collected at this location.

Table 5: Fecal coliform densities per 100 ml for Stoco Lake, 1984.

Date	Stn 1	Stn 2	Near Beach Area
Jul. 24	L2		4
Aug. 01	L4	L4	36
Aug. 15	L4	L4	29
Aug. 20	L10	L10	L10
Sept. 06	L10	L10	L10
Sept. 19	L10	L10	L10

L = less than

The bacteriological sampling program was undertaken specifically in response to complaints that raw sewage discharges to Stoco Lake were occurring. The bacteriological results demonstrated a marked improvement over the results of earlier surveys of Stoco Lake (MOE 1968, 1972). All of the analyses produced low counts of fecal coliform bacteria. The densities of fecal coliform bacteria present were typical of levels present in all surface waters. Where raw sewage inputs occur to surface waters extremely high fecal coliform counts will be detected. The sampling program, while limited in nature, was nevertheless adequate to demonstrate that the concern over raw sewage inputs to Stoco Lake was unfounded.

Inlet and Outlet Water Chemistry

The Ministry of the Environment has maintained five PWQN monitoring stations which supplement survey data for Stoco Lake. The stations are located at the three inlets and the two outlets. The Moira River and the Sulphide Creek inlet stations and the East Channel and West Channel outlet stations were in operation from 1966 to 1980, while the Clare River station has been in continuous operation since 1966. All five stations were sampled as part of the present study. The results

for each sampling date during 1984 are compiled in Appendix 4, while data for the entire periods of record are summarized by yearly means and ranges in Appendix 5.

The primary purpose of inflow monitoring was to investigate nutrient transport via tributary streams as a possible explanation for the state of enrichment of Stoco Lake. The nutrients of greatest concern with respect to the growth of aquatic plants and algae are phosphorus and nitrogen.

During 1984, the average phosphorus concentrations in the inflowing streams to Stoco lake were: Moira River, 33 ug/l; Sulphide Creek, 38 ug/l and Clare River, 25 ug/l. The average phosphorus concentration in the surface waters of Stoco Lake during 1984 was 38 ug/l. Significantly lower phosphorus concentrations were present in the two outlet channels from Stoco Lake during 1984. The West Channel had an average phosphorus concentration of 24 ug/l while the concentrations in the East Channel averaged 27 ug/l.

Total nitrogen concentration in the inflows were: Moira River, 569 ug/l; Sulphide Creek, 640 ug/l; and Clare River, 675 ug/l. These values compare with an average total nitrogen concentration in the lake of 777 ug/l. As for total phosphorus, the total nitrogen concentrations in the outflows were lower than in the lake with concentrations of 690 ug/l and 696 ug/l for the East and West Channels, respectively.

On a net seasonal basis the sediments of Stoco Lake act as a nutrient sink for phosphorus and nitrogen precipitated out of the water column to the lake bottom. Accumulation of nutrients in sediments is not a one way process. Anoxic conditions in bottom waters - a frequent by-product of thermal stratification - enhances the release of phosphorus to overlying waters. Thus, superimposed on the net annual flow of nutrients to the sediments are surges of release to the overlying waters.

The phosphorus and nitrogen concentrations measured during 1984 are comparable to the long term average concentrations based on the periods of record for the PWQN stations as summarized in Appendix 5 and reproduced in Table 6 below.

Total alkalinity and conductivity values are included in Table 6. Conductivity is a measure of the capacity of a sample of water to conduct an electrical current and is proportioned to its total dissolved solids (TDS) content. Alkalinity for lakes in our region is a measure of the carbonate or bicarbonate contribution to the TDS content. Together TDS and alkalinity serve to characterize the general water chemistry of the inflow and outflows. The TDS content and the alkalinities of the inflows for 1984 were slightly higher than the norms established by the PWQN reflecting the preponderance of summer low flow sampling during 1984 as compared to through the year sampling of the PWQN. Otherwise the TDS and alkalinity and thus the other measured parameters during 1984 were typical of the water chemistry of these tributary and outlet streams.

Table 6: Range and mean of total phosphorus, total nitrogen, total alkalinity and conductivity for Stoco Lake inflows and outflows, 1966 - 1984 (from Appendix 5).

Watercourse	Total Phosphorus (ug/l)	Total Nitrogen (ug/l)	Total Alkalinity (mg/l)	Conductivity (umho/cm)
Moira River M1 (17-0026-006-02)	30 (7-359)	696 (358-4290)	65 (34-97)	146 (74-230)
Clare River C1 (17-0026-007-02)	28 (7-310)	713 (343-1713)	133 (20-173)	274 (90-374)
Sulphide Creek S1 (17-0026-008-02)	50 (3-310)	673 (330-5517)	72 (21-141)	187 (74-387)
West Channel M2 (17-0026-003-02)	48 (13-850)	790 (333-2721)	74 (46-88)	173 (126-209)
East Channel M1 (17-0026-004-02)	30 (9-167)	737 (393-1765)	76 (57-112)	175 (130-414)

Anomalous value for total phosphorus of 3,500 ug/l for Sulphide Creek excluded from Table.

Considering phosphorus and nitrogen, phosphorus is commonly the least abundant relative to the nutritional requirements of algae and thus generally limits biological productivity. A mathematical model has been developed which relates the trophic status of a lake in terms of its summer mean chlorophyll concentration to its phosphorus budget (Dillon, 1975). The phosphorus data from the tributary sampling during the present study and from the PWQN since 1966 were used to develop a phosphorus budget for Stoco Lake.

WATER QUALITY MODEL - NUTRIENT SOURCES

A watershed nutrient modelling approach (Dillon, 1975) was used to estimate the significance of various sources of phosphorus to the water quality of Stoco Lake. The model recognizes the importance of phosphorus in the eutrophication (water quality deterioration) process. In simple terms, the model estimates the quantity of phosphorus supplied to the lake on an annual basis and uses the supply to predict the resulting concentration of phosphorus in the lake. As the phosphorus concentration in the lake increases, increased growth of phytoplankton (algae) causes turbid water and a general decline in water quality. The decline in water quality restricts its recreational potential. Table 7 relates recreational use and trophic status to phosphorus concentrations of a lake.

Table 7: Relationship among average total phosphorus concentrations, level of lake productivity (trophic state) and recreational use.

Phosphorus Concentration (ug/l)	Trophic State	Lake Use
L10	oligotrophic	Excellent for water-based recreation, extremely clear water with very little biological productivity.
10 - 30	mesotrophic	Good for water-based recreation but less clear water with moderate biological activity.
G30	eutrophic	Reduced suitability for water-based recreation by high concentrations of phytoplankton resulting in very turbid water, body contact recreation eg. swimming may be restricted at times by periodic algal blooms. Generally very productive for warm water fisheries.

L = less than G = greater than

Sources of phosphorus are:

1) Tributary drainage - both water soluble and insoluble phosphorus are removed by runoff. Cleared agricultural land contributes a greater amount of phosphorus than forested areas because of its greater susceptibility to erosion and because of the applications of chemical fertilizer and manure.

2) Atmospheric precipitation directly on the lake surface. The precipitation may be in the form of moisture such as rain or snow or in the form of dry fallout such as dust, pollen or seeds.

3) Artificial input - from sewage and septic tank tile bed effluent.

The phosphorus supplied from tributary drainage was estimated by summing the supplies of each sub-watershed as determined by multiplying the average yearly discharge of water (Table 1) from each by the mean yearly phosphorus concentration (Table 6) in its tributary stream:

Subwatershed	Discharge $10^6\ m^3\ yr^{-1}$		Phosphorus $mg\ m^{-3}$		Supply $Kg\ yr^{-1}$
Moira River	750.3	x	30	=	22,509
Clare River	159.3	x	28	=	4,460
Sulphide Creek	82.5	x	50	=	4,125

The atmospheric supply was calculated by the application of a bulk atmospheric coefficient of 50 mg. m^{-2} (Dillon et. al., 1978) to the surface area of Stoco Lake.

$$50\ mg.\ m^{-2} \times 500\ ha = 250\ kg.$$

To calculate the total natural phosphorus supply, the drainage basin phosphorus is added to the phosphorus in precipitation falling directly on the lake.

$$31094\ kg + 250\ kg = 31344\ kg$$

The artificial phosphorus supply to a lake originates in leachate from septic tank systems and from any point source inputs (PSI).

The artificial supply from septic tanks was calculated from an average yearly per capita contribution of 0.8 kg. $yr.^{-1}$ and the number of capita-years per year spent on the lake at dwellings serviced by septic tank systems:

$$0.8\ kg\ P/capita\text{-}yr. \times N_{CY}$$

The total number of capita-years was calculated by adding together the permanent resident capita-years, the seasonal resident capita-years and the transient user campsite capita-years. In Southern Ontario the average occupancy rate for cottages is 72 days per year based on an average of 3.9 people per cottage, (0.77 capita-years per year), for permanent residences 3.9 capita-years per year, and for campsites 0.5 capita-years per year. This information was combined with the shoreline development statistics from [redacted] Fig. 2 and inserted into the above equation to estimate an artificial phosphorus supply of 364 kg $yr.^{-1}$ from septic tanks.

$$0.8 \text{ kg P/capita - yr.} \times 455 \text{ capita - yr.} = 364 \text{ kg}$$

This approach assumes that all phosphorus present in domestic sewage finds its way to the lake. In fact some phosphorus is adsorped on soil in a tile bed or taken up by terrestrial vegetation between the septic tank system and the shoreline. For this reason estimates of the contribution of phosphorus to the lake from shoreline development is a maximum effect estimate based on a worst case assumption.

The seasonal discharge of the sewage lagoon system serving the Village of Tweed is the only point source input to Stoco Lake. The lagoons are discharged twice a year, in the spring and fall, before and after the growing season for aquatic plants and algae, respectively. In 1984 the spring discharge occurred from April 25 to May 15 and the fall discharge in two stages from October 26 to November 11 and December 7 to December 13.

The concentration of phosphorus in the lagoon effluent is monitored to ensure compliance with a Ministry of the Environment objective of an effluent concentration of 1 mg/l or less for discharge to surface waters in the Great Lakes basin. The results of the monitoring for 1984 and earlier years indicate the concentration of phosphorus in the lagoon discharge is less than 1 mg/l (Appendix 7). However, assuming

that the entire volume of the lagoon system is discharged at a concentration of 1 mg/l semi-annually, the supply of phosphorus from this source would be:

$$1.0 \text{ mg/l} \times 229.7 \times 10^3 \text{m}^3 \times 2 = 460 \text{ kg}$$

The total artificial supply of phosphorus to Stoco Lake based on maximum input assumptions is:

$$364 \text{ kg} + 460 \text{ kg} = 824 \text{ kg}$$

The total external phosphorus supply is calculated by adding the artificial supply to the natural supply:

$$31344 \text{ kg} + 824 \text{ kg} = 32168 \text{ kg}$$

Following the quantification of the phosphorus budget, the hydrologic budget for the lake is used to determine the fraction of phosphorus (R) retained by the lake through sedimentation loses to the bottom sediments and the fraction of phosphorus (1-R) that remains in the water column of the lake. This latter quantity of phosphorus, (1-R), is the critical determinant of the lake's enrichment status. Summer mean chlorophyll concentration and water clarity (Secchi disc) are water quality indicators that can be predicted from the phosphorus concentration. Application of the estimated phosphorus supply to the model of lake trophic status predicts lake phosphorus concentration, summer mean chlorophyll concentration and summer Secchi disc visibility depth values for Stoco Lake as tabulated below.

Table 8: Average predicted and measured water quality indicators for Stoco Lake.

Water Quality Indicator	Predicted Value	Measured Value
Phosphorus (mg/m^3)	30.4	38
Chlorophyll _a_ (mg/m^3)	10.3	17.7
Secchi (m)	2.0	1.2

The predicted values are in general agreement with measured values but somewhat underestimate the degree of eutrophy of Stoco Lake. With a response time of .06 years the full effect of phosphorus inputs will be felt in terms of chlorophyll production and algae growth within the same year as the inputs.

For the present study the trophic status of Stoco Lake was already known. The model was used to verify or validate our estimates of the phosphorus supply. The underestimation of the trophic status of Stoco Lake indicates the phosphorus budget for external sources may not have accounted for all the sources of phosphorus to the lake.

The development of anoxic conditions in bottom waters, frequently a by-product of thermal stratification, enhances the resolubilization of nutrients from sediments. In addition to nutrients from external sources, periodic depletion of oxygen in bottom water can cause the release of nutrients from sediments to overlying waters. The release of sediment phosphorus can add significant quantities of phosphorus to the water column. This internal load can contribute to water quality problems, however the effect varies greatly among lakes depending upon their morphometry (size and shape) and in lake mixing processes.

In lakes that are deep and develop stable thermoclines, the hypolimnetic build-up is not available to phytoplankton since it remains in the hypolimnion (bottom water) until the fall overturn. In Southeastern Ontario the fall overturn occurs in late October to early November, usually well past the growing season for aquatic plants and algae.

The thermocline in shallow lakes is easily disrupted by wind action resulting in phosphorus transport to the epilimnion and oxygen to the hypolimnion. Consequently, the contribution and availability of phosphorus intermittently throughout the summer is a more common phenomenon in shallow lakes where thermocline disruption may be a frequent occurrence than in deep lakes with stable stratification.

Our study documents the formation of a transient hypolimnion in Stoco Lake which is accompanied by dissolved oxygen depletion and a concommitant build-up in the concentrations of iron, phosphorus and nitrogen. The internally derived phosphorus is mixed into the euphotic zone during periods of wind-induced mixing and becomes available for phytoplankton growth during the summer months when other sources of phosphorus have slowed up or ceased. This internal loading mechanism was not accounted for in our nutrient budget model.

As the estimates of external phosphorous supply were based on monitored data or maximum input assumptions for septic tank leachate and the lagoon discharge, the discrepancy between the predicted water quality indicators and the measured values must either be a lack of precision in the model or be attributed to this internal source of phorphorus. It is probable in the case of Stoco Lake that the internal source of phosphorus accounts for the discrepancy and must be added to the nutrient budget to account for the total phosphorus supply available for plant growth.

The measured average phosphorus concentration of 38 ug/l was applied to our model lake trophic status and a reverse calculation carried out to predict the magnitude of this internal load. The result of this procedure is a calculated internal source of 8,244 kg of phosphorus that originated from lake sediments.

The phosphorus budget for Stoco Lake including the internal load may be completed as follows:

Table 9: Sources of Phosphorus to Stoco Lake.

Source	Supply kg P per yr.
land (tributary) drainage	31,094
atmospheric precipitation	250
artificial	
shoreline	364
Tweed lagoon discharge	460
regeneration from bottom sediment	8,244
total	40,412

Tributary (land) drainage is by far the major contributor of phosphorus to the lake accounting for 77% of the total supply of 40,412 kg/yr. The second most significant source of phosphorus is the internal supply accounting for 20% of the total supply. Phosphorus regeneration is a minimum estimate due to the assumptions used to derive the artificial source and due to the rapid flushing of Stoco Lake during the spring runoff when most of the tributary load is supplied. It is noted that the exchange rate of Stoco Lake is 50 times its volume annually. This extremely high flushing rate confirms that water quality in the lake is dominated by the inflowing waters, primarily the Moira River. The rapid flushing rate and the extremely shallow nature of the basin ensures that on an annual basis only a small percentage of the incoming phosphorus is lost through precipitation from the water column by sedimentation processes. The balance of the supply remains in the water column to contribute to the very high phosphorus concentration found in the lake.

In an effort to illustrate the effects of inflowing water the model was used to calculate the lake phosphorus concentration assuming no artificial input from septic tanks or the sewage lagoon discharge and

only the natural contribution consisting of the tributary input, atmospheric precipitation and the internal load. An eutrophic lake would still be the result with a predicted phosphorus concentration of 37.4 ug/l.

From this analysis, it may be concluded that the major sources of phosphorus to the system are natural, from land runoff and sediment regeneration. The quality of water in Stoco Lake is eutrophic and it would require more than the elimination of septic tank leachate and lagoon discharges to eliminate the problem of algal blooms.

SUMMARY AND CONCLUSIONS ON THE WATER QUALITY STATUS OF STOCO LAKE

Investigations into the algal problems at Stoco Lake by the present and previous studies indicate algal blooms are normal occurrences caused by the development of ideal growth conditions in a normally productive lake. Phosphorus is the main nutrient limiting growth of algae. In lakes, phosphorus concentrations less than 20 ug/l are non-problematic; whereas, concentrations greater than 30 ug/l often lead to nuisance algal growths. In Stoco Lake, the concentration of phosphorus in the surface waters ranged from 26 ug/l to 58 ug/l during 1984.

Monitoring of phosphorus concentrations in inflowing streams and modelling of the lake's phosphorus budget failed to account entirely for the phosphorus concentrations measured in Stoco Lake. The discrepancy between predicted and measured concentrations was attributed to an internal source of phosphorus contributed through regeneration from lake sediments.

An increase in the bottom water nutrient concentrations was detected between August 1 and August 20, 1984. The build-up was the result of the release of phosphorus from sediments under anoxic (low oxygen)

conditions. Anoxia develops due to the decomposition of settled materials, largely phytoplankton and other phosphorus-bearing organic particulate matter while the lake is thermally stratified. Owing to the shallowness of Stoco Lake relative to its surface area, thermal stratification is generally not persistent from spring to fall turnover. Periods of wind-induced mixing can occur periodically throughout the summer months; however, the extent of de-stratification and depth of mixing are variable. Oxygen-and temperature-profile survey data for the years 1972 to 1975 indicate that complete mixing does not always extend entirely to the bottom waters, as it did in 1984. As a result, the magnitude of this internal source may vary from year to year. In 1984 it accounted for about 20% of Stoco Lake's annual phosphorus budget. Although only 20% of the annual phosphorus supply to the lake, the internal phosphorus supply occurs during the summer months and is available to produce algae during the rapid-growth period. In contrast, a large proportion of the phosphorus supply from land runoff enters and exits the lake during the spring runoff and therefore does not contribute to algal production.

Because of the high concentrations of phosphorus that develop in the deeper waters, the potential for water quality problems is high when breakdown of thermal stratification occurs and the nutrient ladden bottom waters are mixed with the surface waters. If ideal growth conditions of warm, calm, sunny weather, as frequently occur during summer months, follow a period of lake mixing, the ready availability of sediment-derived phosphorus can trigger an algal bloom.

High chlorophyll concentrations indicative of bloom conditions developed during July and August of 1973 and 1975 as well as during 1984, but blooms were not observed in Stoco Lake in either 1972 or 1974.

High chlorophyll concentrations do not necessarily lead to complaints about algal nuisances. During 1984, bloom conditions were apparently aggravated by a light breeze which skimmed the surface of the water and concentrated algae from a large open lake area into a dense mass in a relatively small area along the Greenwood Park beach. This was a localized problem that did not affect other beaches or shorelines on Stoco Lake.

The algal bloom complaint investigation samples collected near shore on July 24 and August 7 contained primarily Lyngbya and Oedogonium, while regular sampling of the mid lake basins contained excessively high numbers of Anabaena and Aphanizomenon. Anabaena and Aphanizonenon are notorious for impairing the recreational and aesthetic qualities of lakes by forming "scums" on the surface of the water. They were likely the major contributing algae to the nuisance accumulations on the Greenwood beach rather than Lyngbya and Oedogonium which wash up in windrows along the shores of Stoco Lake throughout much of the summer.

The sources of phosphorus to Stoco Lake are largely from land runoff with internally derived phosphorus periodically available at critical times throughout the summer. The quality of water in Stoco Lake is eutrophic, and it would require more than the elimination of septic tank leachate and treated sewage effluent to eliminate the problem of algal blooms. The algae conditions in Stoco Lake are not likely to improve; however, based on our lake survey data and observations of past conditions by long term residents on Stoco Lake, it is believed that the nuisance accumulation of algae during 1984 represents an unusual event.

The improvement to sewage disposal practices at the Village of Tweed appears to have eliminated a problem of widespread bacteriological contamination of the lake. The sewage lagoon is discharged in the spring and/or fall when flows in the Moira River are high. The discharge is flushed through Stoco Lake before the growing season and before the weather is suitable for water contact recreational use.

While bacterial levels in Stoco Lake are within Ministry of Environment criteria for recreational use, cottagers are cautioned that all surface waters are subject to occasional contamination by human activity and wildlife, and Stoco Lake should not be used as a source of drinking water supply without prior treatment including disinfection.

It is recommended, as is the current practice, that algal accumulations that develop on the shore in the course of a normal summer be removed by raking, with disposal by burial or composting.

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APPENDIX 1

FACTS

Ontario

Ministry of the Environment

~~Hon. Keith C. Norton, Q.C.~~ Minister

~~Gérard J. M. Raymond~~ Deputy Minister

Algae - What are Algae?

Algae are plants just as trees and grass are. They are green because they contain, as most other plants do, a pigment, chlorophyll, that allows them to manufacture their food in the form of starches or oil by using the energy from sunlight. Other nutrients they can extract from water. They are the most primitive of all plants and they differ from all other plants because each one of their cells can live its life independently from all others in a group.

Algae are an essential food organisms for small microscopic animals at the base of the food chain. They provide the water with oxygen essential to fish. Some species and their amounts in a water body are used as indicators along with other scientific tests to determine the water quality. Because of their rapid reproductive rates algae are used as test organisms for many types of research.

Although algae are microscopic single-celled plant organisms, they may be joined together to form many-celled colonies with a variety of shapes and forms. Some may form spherical clusters, others chains, while others may form long thin branched or unbranched ribbons large enough to be seen with the naked eye. Thousands of species of algae live in a variety of freshwater habitats in Ontario. Many other species are common only to specific environments, such as salt water, the tropics or the arctic, glaciers or hot springs.

Each alga has very specific needs for growth. Those found in lakes are seldom found in rivers and those which populate a lake in summer give way to other forms in winter. Some species can only live in very clean water while others require polluted environments rich in nutrients. No two species of algae have the same requirements for growth but all are governed by various environmental factors such as temperature, light and the concentrations of nutrients such as phosphorus, nitrogen, manganese, iron, silica etc.

Algae are normal inhabitants of nearly all natural surface waters. They form the base of the food chain along with microscopic animal forms such as protozoa and bacteria. As green plants the algae use the dissolved solids, nutrients and minerals in the water and absorb carbon dioxide to grow and reproduce. Bacteria protozoa and other microscopic animals feed on the algae and absorb the oxygen produced by them.

Problems arise in the aquatic environment when the balance between these plant and animal organisms is upset, such as through the introduction of pollutants. An excess growth of algae may be stimulated by changes in the weather, by an increase of nutrients from sewage effluents, land drainage, precipitation or from planktonic masses drifting into a lake from tributary streams.

The general public is not usually aware of these minute algal organisms. However, under special conditions of weather and/or water quality they become so abundant as to create a visible green mass, scum, slime or ooze. In this form they may accumulate on the shoreline and impair the use of that area for recreation or aesthetic pursuits.

...2

Microscopic blue-green algae which grow throughout a lake may become buoyant and concentrate at the surface of the water during quiet weather. A slight onshore breeze can concentrate this buoyant accumulation so that it forms a pea-green scum which fouls beaches as it piles up along the shoreline. Filamentous green algae such as Cladophora attached to natural rocky substrates may be detached by storms and blown on to shore. There they may accumulate in knee-deep mats that rapidly decompose creating a foul smelling black ooze. Less noticeable but equally upsetting are microscopic algae capable of imparting chemical tastes and odours to water. The algae may not be large or abundant but the flavours (cucumber, grassy, musty, fishy etc.,) they impart may make the water undrinkable.

The Ministry of the Environment has facilities for identifying most forms of freshwater algae, be it microscopic free-floating phytoplankton or larger attached forms that appear as visible green strands in the water. A small sample, 1 ounce in size submitted to any of the Ministry's regional offices can, if preserved properly with Lugol's solution, be forwarded to our Toronto Laboratory for analysis.

APPLNDIX 2

FACTS

Ontario

Ministry of the Environment

~~Hon. Keith C. Norton Q.C~~
Minister

~~Gerard J. M. Raymond~~
Deputy Minister

ABOUT SEWAGE TREATMENT October 1982

THE PROCESS AND HOW THEY WORK

Introduction

There are many types of wastewater treatment processes for sanitary wastes but the major treatment methods are variations of the principles which nature uses to purify a river or other body of water. Basically the more essential factors such as sedimentation and the biological breakdown of wastes are speeded up in the treatment plant, with the end result being a quality product which places a minimum amount of strain on the environment. Recently, a chemical method of treatment to reduce the phosphorus content of the effluent has been adapted to the various treatment types and this is seen to be a key factor in controlling nuisance algae in a watercourse.

At present, three basic stages or major treatment methods, are employed in Ontario and these may be categorized as "primary", "secondary" and "tertiary" treatment. In the primary stage, solids are allowed to settle and are removed as sludge from the water. The secondary stage uses biological processes to purify the wastewater even further. Tertiary processes are now being installed at specified locations to meet more stringent receiving water quality requirements.

It is important to note that over 78%, of Ontario's sewered wastewaters now receive secondary treatment or better.

The efficiency of all treatment whether primary, secondary or tertiary are generally rated in terms of the percentage removal of Biochemical Oxygen Demand (BOD) and the percentage removal of Suspended Solids (SS). BOD is simply the amount of oxygen uptake by bacteria to decompose the wastes and SS are the organic and inorganic substances suspended in the wastewater.

1. Primary Treatment

Wastes entering a plant for treatment, normally pass through a screen to remove certain items such as rags or sticks etc. which may clog pumps or pipes. After screening, the wastes are directed into a grit chamber where sand, small stones etc., are allowed to settle. With the grit removed, the mechanics of settling are further employed to remove the inorganic matter and suspended solids in a primary sedimentation tank or clarifier. The material (sludge) which has finally settled is removed to a digester or other treatment facility where it is suitably stabilized prior to final disposal. Primary treatment generally removes 40 to 60 percent of the suspended solids and in so doing it achieves 30 to 50 percent reduction of BOD. To complete primary treatment, the effluent from the clarifier is usually chlorinated before being discharged to a receiving stream, river or lake. Chlorination reduces the number of disease causing bacteria. The effluent produced from primary treatment is of a lower standard of quality than is achieved in secondary treatment; consequently, this form of treatment is used only when it will meet the water quality requirements of the receiving body of water.

2. Secondary Treatment

The secondary stage of treatment removes up to 90% of the BOD through the action of bacteria and is commonly referred to as biological treatment. The term biological refers to the micro-organisms present in the waste water and these are utilized to break down the organic matter with the end result being a settleable material (sludge), which may be removed, and a clear liquid effluent.

There are various forms of secondary treatment but the "activated sludge process" is by far the most popular method used today. Other forms of secondary treatment such as lagoons and trickling filters are also being used in Ontario but to a lesser extent.

2.1 Activated Sludge Process

The activated sludge process reduces the organic content of the wastes in as short a time as possible by efficiently maintaining the biological activity on the incoming wastes. This is done by introducing a highly developed bacterial community, "activated sludge", to the new wastes as soon as possible, usually at the agitation and aeration sections. The efficiency of this process is ensured by providing a suitable environment for the micro-organisms, which means, supplying optimum amounts of food in the form of wastes, oxygen through aeration and a temperature high enough to maintain the desired growth of the microbes.

The following treatment types, are modifications of the activated sludge process.

a) Conventional Secondary

In this process, the effluent from the primary treatment stage is conveyed to an aeration section where it is thoroughly mixed by the introduction of air for approximately 6 to 8 hours. The air provides sufficient oxygen and contact through agitation with the new wastes to ensure that an efficient decomposition of the wastes occurs. An optimum balance between the incoming food, (primary effluent) and the population of the mixed biological community is maintained by adding a portion of the activated sludge to the beginning of the aeration section. Excess activated sludge together with some liquids are directed to the digesters where they receive further treatment. A clear high quality effluent is produced and the removal of BOD and suspended solids ranges from 90 to 95 percent.

b) High Rate

The high rate modification was developed by overloading the conventionally designed activated sludge plants. The organic load in the aeration sections is the highest of any of the other variations of the activated sludge process and the aeration time is proportionately shorter (1 to 3 hours). Excess activated sludge and some liquids are placed in a digester where they are stablized before final disposal. A higher volume of wastes may be handled in a shorter period of time, which makes for a more economical operation. A primary treatment section may or may not be present, and this method is generally used where industrial wastes are encountered.

The high rate type of treatment is reported to have a removal rate for BOD and suspended solids in the 80 to 85 percent range.

c) Extended Aeration

The incoming wastes are immediately placed in an aeration section without primary settling and a longer aeration time is employed usually 18 to 24 hours. Due to the long aeration period a more complete decomposition or oxidation of the wastes occurs.

As with the conventional secondary, a high level of biological activity is maintained throughout the aeration tank by returning some of the activated sludge to the raw sewage influent. Excess activated sludge together with some liquids are placed in a holding tank or sometimes a digester prior to final disposal. The reduction in BOD is usually in excess of 90%.

d) Contact Stabilization

This modification provides a means of varying the contact time between the incoming wastes and the activated sludge. The initial operation is done in a small chamber called a contact aeration tank and usually lasts for 1 or 2 hours. After this short aeration period the wastes undergo settling and the resulting sludge is re-aerated for a further 2 to 6 hours. The total aeration times of the sludge ranges from 3 to 8 hours which allows for the production of the activated sludge required in the contact aeration tank. Excess activated sludge together with some liquids are placed in a holding tank or sometimes a digester prior to final disposal.

The removal of suspended solids and BOD is similar to the conventional secondary method.

e) Oxidation Ditch

An oxidation ditch is a retention channel constructed in the shape of a race track which is equipped with a rotary aerating device, which circulates the wastewater around the channel where the activated sludge process is employed. After the required retention time the treated wastewater is drawn off as new wastes are added, and placed in a settling tank where the sludge is collected and then either returned to the ditch or removed for final disposal. The effluent from the settling tank is clear and of good quality. The removal of BOD and suspended solids ranges from 85 to 90 percent. This process is similar to extended aeration and is usually used in smaller communities.

2.2 Lagoons, Aerated Cell and Aerated Lagoon

A lagoon is a flat bottomed structure composed of earth dikes and sized to retain the wastewater for a designated period of time. The lagoon employs many complex systems working together in a cyclical manner. For example, the bacteria converts the organic matter into available plant food and promotes the growth of algae, which is one of the simplest forms of plant life. The algae, with the aid of sunlight, produces oxygen which is required to maintain good bacterial activity on the incoming wastes. Also, the bacteria, with sufficient food (wastes), grow and give off carbon dioxide, which is needed to sustain the algae's life cycle. During the retention period these natural processes work together to decompose and effectively stablize the wastes. The efficiency of these processes are dependent on several factors such as liquid depth, temperature, algae growth, waste characteristics, etc. When conditions are at an optimum, then a good quality effluent may be expected.

Some lagoons, or waste stabilization ponds may be aerated, by either mechanical stirring or the bubbling of air into one small cell (aerated cell) or throughout the entire lagoon (aerated lagoon). Aeration reduces the retention period, increases the capacity of the existing lagoon and is useful in treating some industrial wastes. 80 to 85 percent removal of BOD and suspended solids may be expected.

2.3 Trickling Filter

The trickling filter is simply a bed of stones from 3 to 6 feet deep to which primary treated sewage is equally distributed. Bacteria adhere to and multiply on the surfaces of these stones until they can consume most of the organic matter. Treated water trickles out through a network of pipes in the bottom of the filter where it is collected and directed to a final clarifier before final disposal. BOD and suspended solids removal by this process has been reported from 75 to 90 percent. Trickling filters have generally been employed in the more temperate climates.

3. Tertiary Treatment

Tertiary treatment processes are applied to secondary effluent to further upgrade the effluent quality for specific receiving water needs.

In Ontario, the only tertiary processes being used on a municipal scale are polishing lagoons and tertiary effluent filtration. These are designated as "effluent polishing" in this publication.

a) Polishing Lagoons

Polishing lagoons offer an opportunity for increased BOD and suspended solids removal at a minimum of cost but require a relatively large land area. Secondary effluent is passed into lagoon where it is retained for several days while the algae-bacterial symbiotic relationship is encouraged to optimize oxidation of the organic waste. A fairly consistent removal of BOD is maintained throughout the year. There is a marked increase in effluent suspended solids during the summer months when algal activity is at its peak and this constitutes a major disadvantage of the polishing lagoon. BOD removals in the order of 40 to 60% from a secondary effluent may be achieved.

b) Effluent Filtration

Filtration of secondary effluent is the most widely applied tertiary process in Ontario. A well designed and operated tertiary filter should achieve a good lowering of suspended solids and is effective in reducing BOD and total phosphorus.

4. Phosphorus Removal

Treatment for phosphorus basically consists of the addition of a chemical which through precipitation lowers the phosphorus in the effluent to a specified amount. Phosphorus must be reduced to one part per million (1 ppm) or milligram per litre (mg/l) in all designated plants in the Lower Great Lakes drainage basin. Designated plants in the Upper Great Lakes and Ottawa River drainage basins must reduce influent phosphorus by 80 percent or to 1 ppm. Phosphorus removal facilities can be incorporated into any existing treatment works and the chemicals generally used are lime, aluminium salts or iron salts. New chemicals to be used in any plant must first undergo treatability studies to determine if the desired reduction of phosphorus is achieved with no upset in plant operation and to ensure that the quality of effluent has not suffered any deterioration.

Important side benefits of increased removal of organic material and suspended solids occur when phosphorus treatment is employed in primary plants and lagoons with seasonal discharge. Secondary plants and continuous discharge lagoons do not enjoy these benefits; however, secondary plants report better settling in the final stages.

APPENDIX 3a: Water chemistry results for Station 1, Stoco Lake north basin (Stn. Id. 17-0026-714-01)

Date 1984	depth	Secchi	chlorophyll a	hardness	alkalinity	conductivity	pH	calcium	magnesium	chloride	iron	colour	total phosphorus	soluble phosphorus	ammonia N	Kjeldahl N	nitrite N	nitrate N
		m	ug/l	mg/l	mg/l	umho/ cm		mg/l	mg/l	mg/l	mg/l	hazen	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Aug. 1	s	1.2	22.5	99	91	190	8.6	32	4.8	4.3	0.15	32	48	14	10	870	2	L20
				104	93	200	7.6	33	5	4.5	0.40	44	28	6	60	570	6	L20
Aug. 7	s	0.9	21.1										34	10	10	660	6	L20
Aug. 15	s	1.2	17.0	96	87	185	8.3	31	4.5	3.5	L.05	33	42	12	10	710	2	L20
	b			101	90	195	8.7	33	4.6	3.8	0.10	56	44	12	70	550	8	L20
Aug. 20	s	1.0	12.4	101	94	195	8.1	33	4.7	4	L.05	45	42	10	L10	750	L2	L20
	b			100	93	195	7.8	32	4.8	4	L.05	55	62	14	90	800	2	L20
Aug. 28*		0.8	24.4															
Sept. 4*		0.7	9.7															
Sept. 6	s	0.8	22.2	104	93	195	7.7	33	5.1	4	0.15	26						
	b			105	94	195	7.9	34	5.1	4	0.10	27	36	8	140	820	4	
Sept. 12*		1.1	13.7															
Sept. 19*		1.0	16.2															
Sept. 19	s	1.0	17.4	102	91	200	7.9	33	5.0	5	0.10	24	36	4	10	790	L2	L2
	b			103	89	200	7.9	33	5.0	4	0.10	26						
Sept. 24*		1.4	18.5															
Oct. 15	s	3.0		106	89	200	7.9	34	5.4	5	0.10	18	58	4	100	710	4	L2
	b			106	91	205	7.7	34	5.4	5	L.05	23	44	10	160	760	6	L2
Mean	s	1.2	18.1	101	91	194	8.1	33	4.9	4	0.10	30	43	9	25	756	3	L20
	b			103	92	194	7.9	33	5.0	4	0.13	38	43	10	104	700	4	L20

s = surface sample
b = bottom sample
* = samples provided by A.G. Oliver through participation in Ministry of Environment - Cottagers Self - Help Water Quality Monitoring Program
L = less than

APPENDIX 3b: Water chemistry results for Station 2, Stoco Lake south basin (Stn. Id. 17-0026-714-01)

Date 1984	depth	Secchi m	chlorophyll a ug/l	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Jul. 24	s	1.8	5.4	101	87	195	8.1	28	3.9	4.5	0.10	48	28	6	L10	660	L2	L20
	b			86	81	185	7.0	33	4.5	4.3	0.30	94						
Aug. 1	s	1.5	17.2	98	89	190	8.5	32	4.6	4.0	0.10	35	36	12	L10	780	4	L20
	b			95	85	190	7.3	31	4.3	3.8	L.05	99	26	8	140	680	L2	L20
Aug. 7	s	1.0	20.6										28	8	10	810	L2	L20
Aug. 15	s	1.0	16.0	93	84	185	8.1	30	4.5	3.5	0.10	33	38	12	20	660	L2	L20
	b			94	80	190	7.5	30	4.5	3.8	1.0	198	48	12	420	830	L2	L20
Aug. 20	s	1.0	15.1	92	87	180	8.1	30	4.4	4	L.05	44	42	8	L10	790	L2	L20
				172	85	200	7.4	60	5.2	4	L.05	190	106	16	730	1350	L2	L20
Aug. 28*		0.8	21.3															
Sept. 4*		0.7	6.3															
Sept. 6	s	0.9	21.4	99	89	185	8.0	32	4.7	4	0.05	23	36	8	120	840	2	
				98	88	185	7.9	31	4.7	4	0.05	23	40	4	140	800	2	
Sept. 12*		1.1	12.5															
Sept. 19*		1.0	13.8															
Sept. 19	s	1.0	17.4	97	86	190	8.0	31	4.7	4	0.10	26	34	4	20	800	L2	L2
	b			95	83	185	7.9	30	4.8	4	0.15	36						
Sept. 24*		1.4	17.4															
Oct. 15	s	3.0		99	79	200	7.9	32	4.7	7	L.05	16	26	4	70	660	4	L20
	b			98	82	200	7.8	31	4.7	5	0.10	20	30	8	160	690	4	20
Mean	s	1.2	15.4	97	86	189	8.1	31	4.5	4.4	0.8	32	34	8	30	750	2	20
	b			105	83	191	7.5	35	4.7	4.1	0.25	94	50	10	320	870	2	20

s = surface sample
b = bottom sample
* = samples provided by A.G. Oliver through participation in Ministry of Environment - Cottagers Self - Help Water Quality Monitoring Program
L = less than

APPENDIX 4a: Water chemistry results for Station M1, Moira River inlet (PWQM Stn. Id. 17-0026-006-02) for 1984.

Date 1984	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Mar. 05			167				4.17			10		44			
Aug. 01	57	53	120	7.6	18	2.8	2.5	0.40	45	26	4	10	520	4	40
Aug. 07	53	45	162	7.7	17	2.4	L2.5	0.60	44	34	6	10	660	L2	60
Aug. 15	66	57	142	7.9	21	3.0	3.3	0.20	35	32	4	20	520	4	100
Aug. 20	91	82	185	8.0	30	4.2	5	L.05	43	30	4	L10	620	L2	20
Sept. 06	85	77	165	7.8	28	3.7	4	0.10	25	26	10	80	1100	2	40
Sept. 19	95	83	195	7.9	31	4.2	5	0.20	26	20	2	30	520	L2	40
Oct. 15	112	97	230	8.0	37	5.0	7	0.20	34	20	4	20	540	4	40
Oct. 26		84	205	8.0			7	0.20	41	120	100	40	520	4	40
Oct. 29		89	215	7.9	35	4.6	7	0.25		20	6	40	480	4	40
Nov. 01		91	215	8.0			7		31	26	8	50	540	6	60
Nov. 06		69	160	7.7			5	0.20	52	26	4	10	480	4	60
Nov. 08		70	170	7.9			5	0.25	53	22	6	30	530		70
Dec. 07		86	195	7.9			7	0.15	40	L40	4	60	500	6	70
Dec. 10		86	200	7.8			6	0.20	38	L40	4	50	500	2	80
Dec. 13		77	195	8.0			6	0.15	40	40	6	50	500	4	80
Mean	80	76	183	7.9	27	3.7	5.2	0.23	39	33	11	35	569	4	57

L = less than

APPENDIX 4b: Water chemistry results for Station S1, Sulphide Creek inlet (PWQM Stn. Id. 17-0026-008-02) for 1984.

Date 1984	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Aug. 01	131	121	271	7.5	42	6.4	6.5	0.40	53	46	14	50	730	2	L20
Aug. 07	141	125	188	7.5	44	7.3	7.8	0.80	45	54	22	40	740	2	40
Aug. 15	84	49	195	7.7	26	4.9	8.0	0.60	57	36	6	50	720	4	60
Aug. 20	65	51	142	7.6	21	3.3	6	L.05	91	38	10	10	760	2	20
Sept. 06	105	82	215	7.6	33	5.6	8	0.50	31	30	8	30	560	10	30
Sept. 19	78	57	175	7.6	24	4.4	9	0.80	36	24	10	50	560	L2	20
Oct. 15	144	115	300	7.5	45	7.9	11	0.55	58	36	8	L10	550	L2	L20
Oct. 29	126	103	260	7.4	39	6.7	9	1.0		42	6	60	510	2	L20
Mean	109	88	218	7.6	34	5.8	8.1	0.60	53	38	10	40	640	3	30

L = less than

APPENDIX 4c: Water chemistry results for Station C1, Clare River inlet (PWQM Stn. Id. 17-0026-007-02) for 1984.

Date 1984	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Jan. 09		129	292	8.2			4.3			15		40			
Feb. 08		136	308	7.3						16		64			
Apr. 09			192	7.7			4.1			16		18			
Jun. 04		126	272	8.3			3.4			21		16			
Jul. 09		166	326	8.2			2.0			20					
Aug. 01	171	164	311	7.8	55	8.5	3.3	0.10	43	30	4	10	900	L2	L20
Aug. 07	178	171	315	7.8	57	8.7	3.3	0.55	38	30	2	L10	620	L2	L20
Aug. 15	136	129	260	7.8	43	7.0	3.3	0.05	54	30	6	40	670	2	L20
Aug. 20	135		251	7.7	43	7.0	4	L.05	67	34	8	10	740	2	20
Sep. 06	154	144	275	7.7	49	7.7	4	0.10	35	26	6	50	640	2	L20
Sep. 19	160	151	300	7.9	50	8.4	4	0.20	32	22	6	40	620	L2	L2
Oct. 15	172	156	320	7.7	54	9.1	5	0.20	54	32	6	L10	640	L2	L20
Oct. 29	172	162	325	7.7	53	9.3	5	0.45		36	8	40	570	L2	L20
Mean	160	149	288	7.8	50	8.2	3.8	0.20	46	25	6	29	675	L2	L20

L = less than

APPENDIX 4d: Water chemistry results for Station M2, Moira River west channel outlet (PWQM Stn. Id. 17-0026-003-02) for 1984.

Date 1984	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Mar. 05			171				4.0			G4		64			
Aug. 01	101	91	205	8.4	32	4.9	6.5	0.10	27	16	6	L10	670	L2	L20
Aug. 07	96	86	191	8.4	31	4.4	5.0	0.40	33	46	10	L10	800	L2	L20
Aug. 15	88	81	180	8.0	28	4.2	5.3	0.10	37	36	8	30	650	4	100
Aug. 20	98	87	185	8.2	32	4.5	4	L.05	44	34	10	L10	720	L2	L20
Sep. 06	100	88	185	7.9	32	4.8	4	0.05	23	30	8	80	850	L2	L20
Sep. 19	104	94	215	7.9	33	5.2	8	0.10	23	24	2	20	590	L2	L20
Oct. 15	105	89	205	7.9	34	5.1	5	0.10	26	22	4	60	610	4	40
Oct. 29	106	91	210	8.0	34	5.3	6	0.10	36	4		30	640	4	20
Mean	100	88	194	8.1	32	4.8	5.3	0.12	31	24	7	35	690	L3	L32

L = less than
G = greater than

APPENDIX 4e: Water chemistry results for Station M3, Moira River east channel outlet at Stoco Bridge (PWQM Stn. Id. 17-0026-004-02) for 1984.

Date 1984	hardness mg/l	alkalinity mg/l	conductivity umho/cm	pH	calcium mg/l	magnesium mg/l	chloride mg/l	iron mg/l	colour hazen	total phosphorus ug/l	soluble phosphorus ug/l	ammonia N ug/l	Kjeldahl N ug/l	nitrite N ug/l	nitrate N ug/l
Mar. 05			172				4.7			9		46			
Aug. 01	100	89	195	8.0	32	4.6	4.0	0.15	40	36	14	10	810	L2	L20
Aug. 07	95	85	185	8.4	31	4.3	4.0	0.55	41	40	10	L10	760	6	L20
Aug. 15	92	83	180	8.4	30	4.3	3.8	0.10	37	38	12	10	710	2	L20
Aug. 20	96	87	185	8.1	30	4.9	4	L.05	42	34	8	L10	690	L2	L20
Sep. 06	98	87	185	7.8	32	4.6	4	0.05	23	8	8	110	740	2	L20
Sep. 19	93	85	191	7.8	30	4.4	4	0.10	23	28	4	60	690	L2	20
Oct. 15	100	88	200	8.0	32	4.8	5	.05	26	26	6	50	650	2	40
Oct. 29	101	90	205	7.9	32	5.0	5	0.15		26	4	40	520	4	40
Mean	97	87	189	8.0	31	4.6	4.3	0.15	33	27	8	38	696	L3	L25

L = less than

APPENDIX 5a: Mean, range and number of samples (n) for total phosphorus (ug/l), total nitrogen (ug/l), total alkalinity (mg/l) and conductivity (umho/cm) for Moira River inlet at Tweed (PWQM Stn. Id. 12-10026-006-02)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1966	31	6	780	2	62	3	134	5
	(13-65)		(490-1070)		(34-87)		(92-207)	
1967	77	10	1282	6	58	9	152	11
	(7-359)		(568-4290)		(39-67)		(98-167)	
1968	41	9	835	8	70	9	159	10
	(20-88)		(545-1426)		(62-84)		(110-192)	
1969	42	12	715	11	72	5	167	12
	(20-70)		(358-1099)		(57-81)		(90-216)	
1970	35	7	635	7	56	6	140	8
	(22-50)		(486-946)		(38-78)		(93-171)	
1971	31	9	651	9	62	2	137	9
	(24-42)		(513-719)		(60-64)		(88-162)	
1972	34	10	723	10	65	3	165	10
	(26-45)		(481-1110)		(63-66)		(128-181)	
1973	35	11	662	11			134	11
	(18-51)		(454-1042)				(74-170)	
1974	39	8	679	8			139	8
	(19-71)		(513-1122)				(94-193)	
1975	27	10	536	10			134	10
	(16-36)		(453-655)				(84-190)	
1976	25	12	638	12			147	12
	(14-40)		(437-1072)				(96-185)	
1977	30	8	620	8			139	8
	(23-42)		(490-960)				(90-185)	
1978	34	6	651	6			130	6
	(24-66)		(519-960)				(84-185)	
1979	25	10	660	10			128	10
	(17-40)		(427-941)				(95-170)	
1980	17	2	690	2			172	2
	(14-20)		(656-725)				(165-180)	
1984	33	16	630	15	76	15	183	15
	(10-120)		(480-1142)		(45-97)		(120-230)	
Maximum	359		4290		97		230	
Mean	30		691		67		148	
Minimum	7		358		34		74	
No.	(146)		(135)		(52)		(148)	

APPENDIX 5b: Mean, range and number of samples (n) for total phosphorus (ug/l), total nitrogen (ug/l), total alkalinity (mg/l) and conductivity (umho/cm) for Clare River (PWQM Stn. Id. 12-0026-007-02)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1966	24	3			142	1	347	2
	(7-46)						(320-374)	
1967	26	3	818	1	110	4	244	4
	(7-36)				(79-146)		(137-333)	
1968	25	3	750	3	115	3	273	4
	(23-29)		(414-921)		(30-167)		(205-344)	
1969	58	4	555	3	126	3	297	4
	(20-160)		(416-723)		(90-147)		(207-369)	
1970	28	3	638	3	137	3	274	4
	(24-30)		(536-804)		(92-162)		(218-330)	
1971	36	3	876	3	167	2	285	3
	(16-56)		(397-1713)		(160-173)		(192-339)	
1972	25	6	593	6	111	1	262	6
	(19-33)		(408-674)				(174-305)	
1973	30	11	641	11			273	11
	(15-67)		(344-1212)				(195-330)	
1974	63	8	603	8			257	8
	(13-310)		(515-757)				(180-310)	
1975	25	9	550	9			294	9
	(15-36)		(343-753)				(200-345)	
1976	20	10	608	10			294	10
	(11-28)		(436-887)				(155-355)	
1977	22	8	561	8			312	8
	(14-31)		(475-700)				(232-345)	
1978	19	5	563	5			276	5
	(13-25)		(428-808)				(225-325)	
1979	26	9	613	9			255	9
	(14-55)		(455-795)				(178-300)	

APPENDIX 5b: (continued)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1980	22	11	632	2	125	9	265	11
	(12-38)		(604-660)		(82-160)		(180-320)	
1981	23	9			127	9	244	9
	(8-34)				(67-154)		(90-295)	
1982	24	10			124	10	263	10
	(8-33)				(79-148)		(190-301)	
1983	26	11			112	10	262	11
	(12-46)				(20-148)		(245-317)	
1984	25	13	697	8	149	11	288	13
	(15-36)		(592-922)		(126-171)		(192-326)	
Maximum	310		1713		173		374	
Mean	28		622		133		274	
Minimum	7		343		20		90	
No.	(139)		(89)		(63)		(141)	

APPENDIX 5c: Mean, range and number of samples (n) for total phosphorus (ug/l), total nitrogen (ug/l), total alkalinity (mg/l) and conductivity (umho/cm) for Sulphide Creek inlet (PWQM Stn. Id. 17-0026-008-02)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1966	10 (3-7)	2	1600	1	103 (24-82)	2	194 (134-240)	3
1967	104 (39-160)	3	2146 (1200-3207)	3	68 (21-141)	5	206 (137-387)	5
1968	44 (36-52)	2	1030 (1024-1036)	2	66 (55-76)	2	151 (104-215)	3
1969	35 (20-70)	4	535 (376-614)	3	53 (30-73)	3	173 (106-275)	4
1970	1204 (30-3500)	3	1405 (984-2615)	3	82 (34-126)	3	193 (118-296)	4
1971	84 (21-150)	3	1031 (496-1716)	3	78 (70-85)	2	157 (83-200)	3
1972	34 (21-53)	6	686 (480-837)	6	41	1	141 (118-161)	6
1973	54 (22-180)	11	933 (434-2130)	11			171 (94-260)	11
1974	75 (22-210)	8	969 (552-1696)	8			195 (80-299)	8
1975	79 (22-310)	9	1270 (384-5517)	9			211 (110-315)	9
1976	40 (15-86)	12	820 (330-1795)	12			191 (74-320)	12
1977	48 (23-136)	8	815 (625-1080)	8			204 (118-325)	8
1978	55 (23-96)	5	864 (690-1103)	5			219 (131-320)	5
1979	84 (18-295)	9	1079 (547-2575)	9			165 (86-228)	9
1980	20 (17-24)	2	562 (330-794)	2			146 (131-160)	2
1984	38 (24-54)	8	673 (532-784)	8	88 (51-125)	8	218 (142-300)	8
Maximum	3500		5517		141		387	
Mean	86		962		72		187	
Minimum	3		330		21		74	
No.	(95)		(93)		(26)		(100)	

APPENDIX 5d: Mean, range and number of samples (n) for total phosphorus (ug/l), total nitrogen (ug/l), total alkalinity (mg/l) and conductivity (umho/cm) for Moira River East Channel outlet of Stoco Lake (PWQM Stn. Id. 17-0026-004-02)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1966	42	3	690	1			169	3
	(33-46)						(157-182)	
1967	48	9	847	6	66	8	169	10
	(13-167)		(516-1470)		(57-78)		(145-201)	
1968	35	8	659	8	81	8	191	10
	(23-49)		(393-935)		(70-112)		(166-247)	
1969	29	12	898	7	79	5	132	12
	(20-50)		(526-1217)		(60-85)		(90-169)	
1970	44	7	808	6	69	6	167	8
	(30-60)		(537-1164)		(59-82)		(145-200)	
1971	40	9	602	8	66	2	184	9
	(21-62)		(534-923)		(61-70)		(130-414)	
1972	36	10	735	10	75	3	179	10
	(23-48)		(601-1010)		(72-78)		(133-206)	
1973	39	11	765	11			174	11
	(28-98)		(496-1765)				(132-193)	
1974	29	8	686	8			175	8
	(17-38)		(521-983)				(163-190)	
1975	33	11	724	11			164	11
	(23-49)		(474-1115)				(150-200)	
1976	32	12	711	12			173	12
	(22-51)		(467-992)				(130-195)	
1977	38	8	657	8			184	8
	(20-56)		(466-920)				(165-200)	
1978	34	5	640	5			164	5
	(23-58)		(527-747)				(143-175)	
1979	29	10	723	10			158	10
	(17-70)		(520-1060)				(136-175)	
1980	87	2	1126	2			180	2
	(28-145)		(526-1725)				(175-185)	
1984	27	9	724	8	87	8	189	9
	(8-40)		(564-832)		(83-90)		(172-205)	
Maximum	167		1765		112		414	
Mean	30		737		76		175	
Minimum	9		393		57		130	
No.	(135)		(122)		(40)		(138)	

APPENDIX 5e: Mean, range and number of samples (n) for total phosphorus (ug/l), total nitrogen (ug/l), total alkalinity (mg/l) and conductivity (umho/cm) for Moira River West Channel outlet of Stoco Lake (PWQM Stn. Id. 17-0026-003-02)

Year	Total P	n	Total N	n	Alkalinity	n	Conductivity	n
1966	36 (13-52)	3					188 (169-208)	2
1967	179 (26-850)	8	1277 (626-2721)	7	62 (46-75)	8	167 (145-193)	10
1968	37 (20-56)	6	634 (333-753)	4	80 (75-85)	5	181 (160-195)	8
1969	42 (20-70)	12	790 (388-1210)	10	76 (59-88)	5	181 (126-209)	11
1970	52 (30-76)	7	740 (560-972)	7	68 (58-82)	6	162 (141-178)	8
1971	38 (24-50)	7	727 (624-852)	7	72	1	158 (126-176)	7
1972	33 (25-46)	9	740 (602-1091)	9	73 (71-75)	3	176 (137-199)	10
1973	42 (24-80)	11	770 (466-1412)	11			177 (136-200)	11
1974	33 (25-52)	8	709 (562-1023)	8			170 (148-190)	8
1975	35 (22-56)	10	681 (512-1113)	10			157 (130-175)	10
1976	44 (24-93)	11	846 (497-1420)	11			176 (155-200)	11
1977	42 (18-69)	8	772 (497-1440)	8			181 (163-200)	8
1978	47 (21-94)	5	788 (537-1267)	5			165 (143-175)	5
1979	45 (17-116)	10	803 (530-1257)	10			161 (138-175)	10
1980	65 (26-103)	2	998 (676-1320)	2			182 (175-190)	2
1984	24 (4-36)	9	725 (612-872)	8	88 (81-94)	8	194 (171-210)	9
Maximum	850		2721		88		209	
Mean	48		790		74		173	
Minimum	13		333		46		126	
No.	(126)		(117)		(36)		(130)	

APPENDIX 6: Results of phytoplankton analysis of a composite of 8 samples from the south basin at Station 2, July 24 - August 5; and 7 samples from the north basin at Station 1, August 1 - October 15, 1984. Results expressed in thousand cubic microns per ml. (P = present)

	South Basin	North Basin
CYANOPHYCEAE	10^3 u^3	10^3 u^3
Anabaena	1103	2134
Aphanizomenon	431	686
Lyngyba	48	32
Coelosphaerium	24	6
Oscillatoria	63	242
Apanothece	3	3
Microcystis	43	4
Chroococcus	4	4
Total	1719	3111
CHLOROPHYCEAE		
Gloeocystis	16	
Actinastrum	14	P
Closterium	4	3
Chlamydomonas	15	4
Oocystis	P	3
Dictyosphaerium	P	2
Coelastrum		10
Scenedesinus		1
Total	49	58
DINOPHYCEAE		
Ceratium	52	29
CRYPTOPHYCEAE		
Cryptomonas	47	28
Rhodomonas	6	9
Katablepharis	2	1
Total	54	38

BACILLARIOPHYCEAE				
Rhizolenia	88			
Melosira	43		26	
Asterionella	35		107	
Stephanodiscus			42	
Fragilaria			45	
Total	166		220	
CHRYSOPHYCEAE				
Mallomonas		5		38
Unidentified Chrysomonads		3		4
Chrysochromulina parva		2		9
Saplingoeca		3		—
Total		13		51
EUGLENOPHYCEAE				
Euglena				5
ZOOPLANKTON				
Protozoans		28		21

APPENDIX 7: Total phosphorus concentration in Village of Tweed sewage lagoon treated effluent.

Year	Mean Total P (mg/l)	No. of Samples	Range	Median
1984	0.53	16	0.26-0.68	0.60
1981	0.38	6	0.29-0.56	0.355
1980	0.44	10	0.29-0.57	0.435
1979	1.06	4	0.55-1.70	0.99
1978	0.69	27	0.90-2.35	0.36
1977	0.76	6	0.26-1.92	0.47
Mean	0.62	69	0.26-2.35	0.54